Site Specific Condition I.F.11—Results of Test Pad Construction

The results of the test pad construction which details the relationship between the hydraulic conductivity, moisture content, density, borrow source testing, and other assumptions to be used during construction of the liner must be submitted for review and approval prior to construction of the liner.

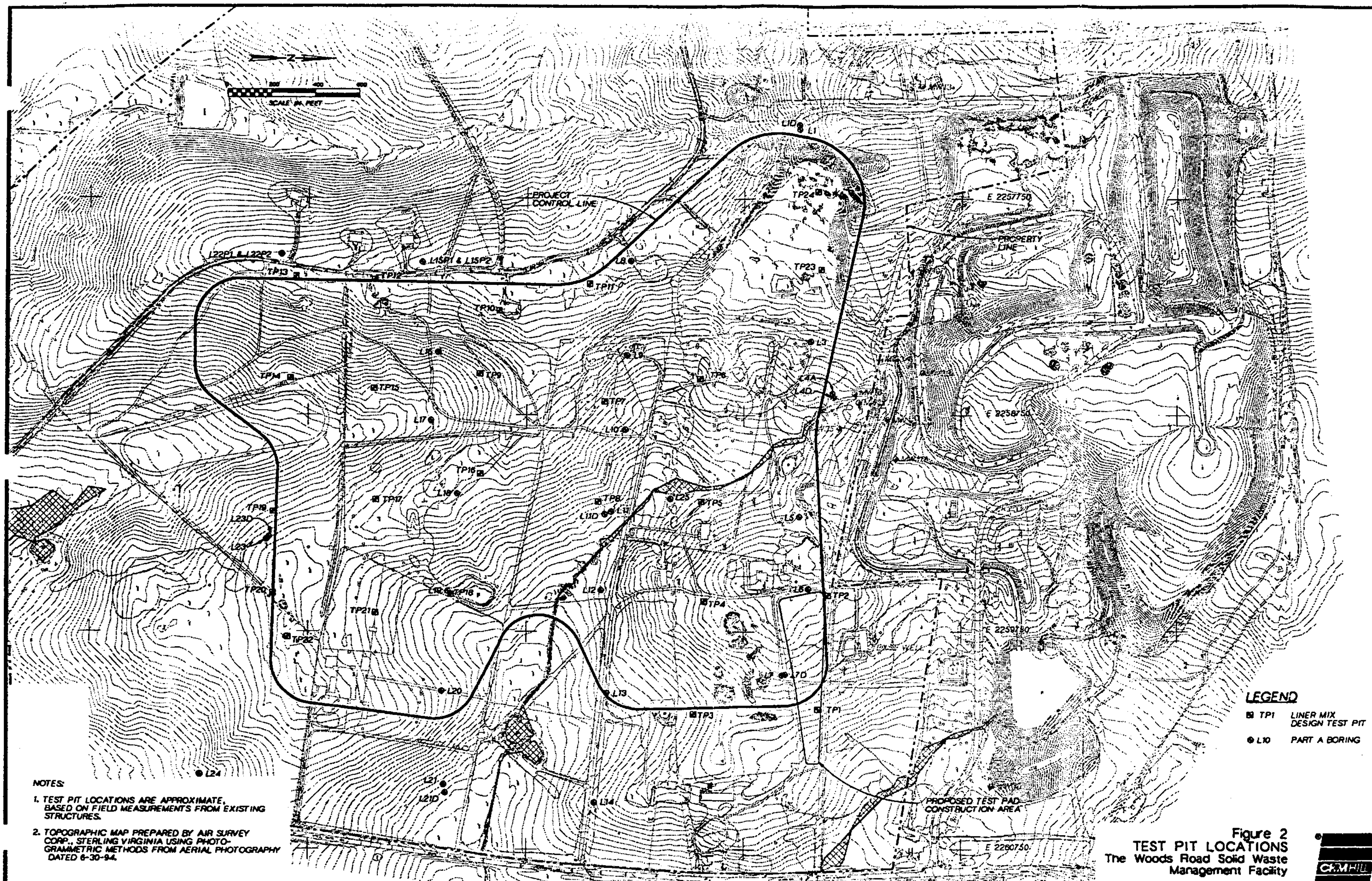
Bentonite-amended soil will be use for construction of low permeability layers (hydraulic conductivities less than 1 x 10^{-7} cm/s) of the composite liner and cover systems for of The Woods Road Solid Waste Management Facility (SWMF). Near surface onsite materials (1 to 9 feet below the ground surface) have been identified as the primary borrow material. These soils have hydraulic conductivities in the range of 1 x 10^{-5} to 1 x 10^{-6} cm/s and therefore, will have to be amended with bentonite to meet the minimum requirements for the project. In order to demonstrate the performance of the bentonite-amended soil, a borrow source study and mix design was conducted to determine the suitability of the bentonite-amended onsite soil for use in the liner and cover systems construction consistent with the Virginia Solid Waste Management Regulations (SWMR) VR 672-20-10. Construction and testing of a full scale test pad was also performed to confirm the performance of the mix design developed based on laboratory testing.

Initially, a borrow source study and bentonite-amended soil mix design were performed on near-surface soils located within the footprint of The Woods Road SWMF. Characterization of these near-surface soils as well as recommendations for moisture content, density, and bentonite application rate are provided in the CH2M HILL technical memorandum entitled *The Woods Road Solid Waste Management Facility Test Pad Design and Construction Bentonite-Amended Soil Mix Design Study*, June 26, 1995 (see Attachment I.F.11-1).

A full scale test pad was constructed to confirm the mix design recommendations and bentonite-amended soil performance under field conditions. The test pad construction and results of laboratory and insitu testing are provided in the technical memorandum entitled *The Woods Road Solid Waste Management Facility Test Pad Design and Construction Test Pad Construction and Testing Phase*, CH2M HILL, September 15, 1995 (see Attachment I.F.11-2).

Conclusion.

The test pad was constructed using near-surface soils located within the footprint of The Woods Road SWMF. Construction methods, techniques, and equipment were specified to simulate actual conditions anticipated during liner and cover construction. The soils were amended with bentonite at an application rate of 7 percent by dry weight and combined with water in a pugmill. The soils were compacted to 95 percent relative compaction in accordance with ASTM D698. An upper (2 percent wet of optimum) and lower (1 percent dry of optimum) moisture content were evaluated. All laboratory and insitu hydraulic conductivity test results were less than 1x10^{-7}cm/s. The onsite bentonite-amended soils meet the requirements of the SWMR.



NOTES:

1. TEST PIT LOCATIONS ARE APPROXIMATE, BASED ON FIELD MEASUREMENTS FROM EXISTING STRUCTURES.
2. TOPOGRAPHIC MAP PREPARED BY AIR SURVEY CORP., STERLING VIRGINIA USING PHOTO-GRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 6-30-94.

LEGEND

TP1	LINER MIX DESIGN TEST PIT
L10	PART A BORING

Figure 2
TEST PIT LOCATIONS
The Woods Road Solid Waste Management Facility

CH2M HILL

Table 1
Summary of Existing Data

Boring Number Sample Depth (ft)	L1D 5	L1D 10	L2 5	L3 7	L4D 7	L5 5	L11 10	L12 7.5	L13 2.5	L13 5	L13 7.5	L16 5	L19 7.5	L19 10	L21 10
Sieve Size	Percent Passing														
#4	90.5	94.2	95.3	97.4	91.3	92.8		100	79.5	94.3	87	98.1	93.7	97.4	94.1
#10	84.8	79.7	82.8	49.8	75.4	82.3		97.4	75.4	76	71.6	81.3	91	93.1	81.2
#18	83.8	78	81.6	46	74.1	78.7		95.7	73.6	75	70.7	80.7	89.8	91.9	78.9
#35	81.8	74.8	79.8	40.8	71.9	72.4		92.8	71.3	73.6	69.2	78.9	87.9	89.7	75.6
#60	78	74.4	77	36.2	68.8	64.8		90	68.8	71.2	67.3	75.5	79.2	87	72.1
#140	60	58.2	68.7	28.2	57.7	49.3		77.7	60.3	51.9	57.9	62.5	76	77.3	64
#200	56.4	51.7	64.7	24.2	50.8	41.5		73.6	57.8	50.5	55.1	55.2	72.9	71.2	57.7
.0156 mm	39.4	35.4	51.9	14.2	33.8	23.3		53.3	43	38.3	39.4	41	55.6	56.4	44.6
.0039 mm	18.6	13.6	36.6	5.4	13.4	10.7		27.9	26.2	23.2	19	25.8	37.8	37.3	19.8
.002 mm	10.6	5.5	31.7	3	6	5.8		18.7	16.6	14.6	11.8	20.3	29	31.2	11.7
USCS Classification	ML	ML	ML	SM	ML/SM	SM		ML	SM	ML/SM	ML/SM	ML	ML	ML	ML
Natural Moisture Content (%)							16.4								
Dry Unit Weight (pcf)							106.6								
Hydraulic Conductivity (cm/s)							4.6×10^{-5}								
Specific Gravity							2.66								
Porosity							0.36								

- Phase 3–Moisture-density versus hydraulic conductivity testing
- Phase 4–Variability performance testing

Phase 1–Characterization

Laboratory Testing

The first phase of laboratory testing consisted of characterization testing of all bulk samples collected from the 24 test pits. The purpose of this testing was to characterize the gradation and plasticity range of near surface materials across the site, and to identify the two coarsest, and one finest samples for further testing. These samples were assumed to be representative of the full range of soils on the site.

The following test were performed on each test pit sample:

- Grain Size Analysis (ASTM D422)
- Atterberg Limits (ASTM D4318)

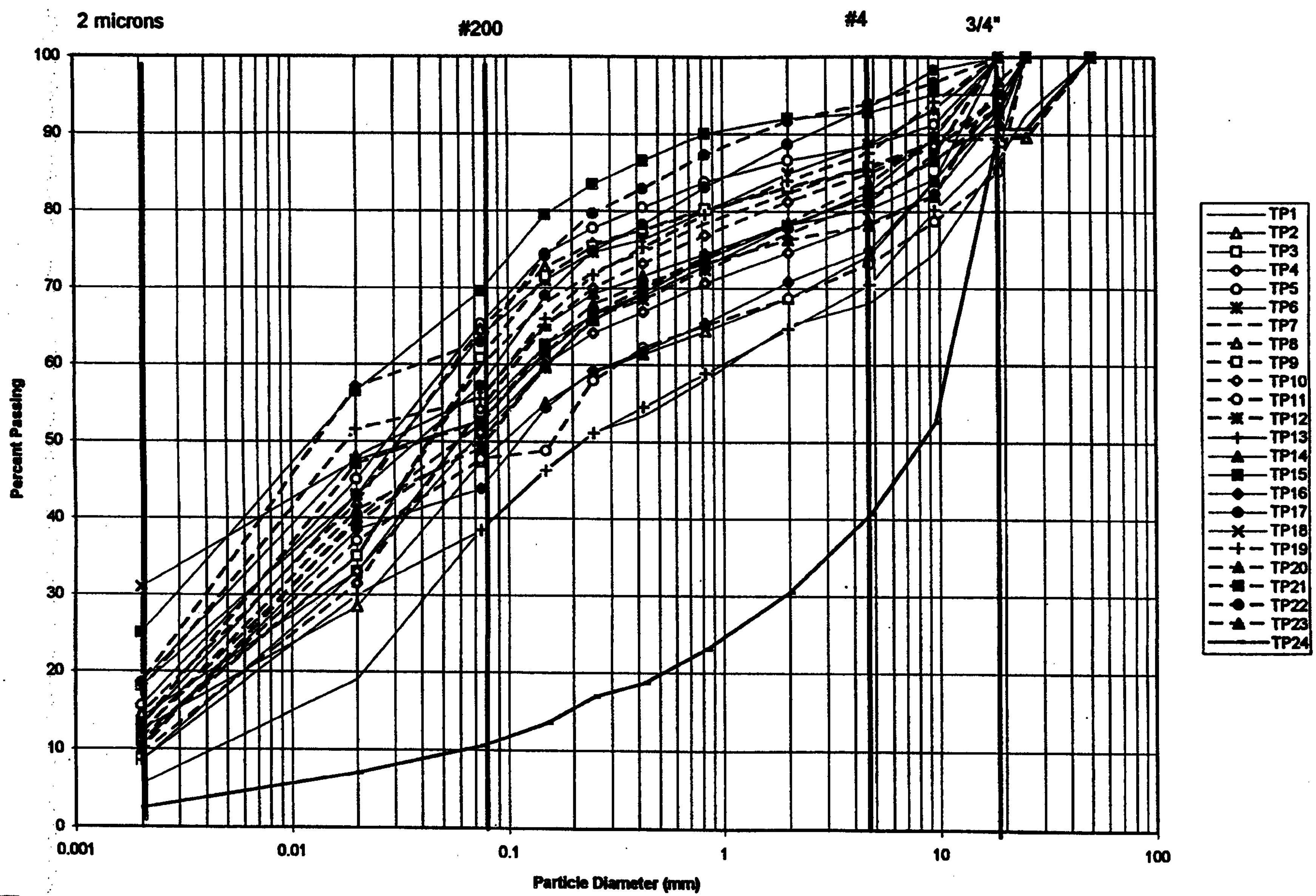
All laboratory testing was performed by Law Engineering, Inc., of Chantilly, Virginia, the County's geotechnical consultant. Attachment B contains documentation of the laboratory testing methods used by Law.

Laboratory Results

The results of the characterization testing performed on the 24 test pit bulk samples are summarized in Table 2. Six of the samples were classified as silty sand (SM), 13 were classified as a silt (ML), 3 were classified as clay (CL), 1 was classified as elastic silt (MH), and 1 was classified as poorly graded gravel with silt (GP-GM) in accordance with the Unified Soil Classification System, ASTM D2487. Liquid limits for these materials ranged from 29 to 53 and plasticity indices ranged from non-plastic to 20. Sieve analyses indicate that 0 to 14.8 percent of these materials are retained on the 3/4-inch sieve, 38.4 to 65.3 percent of these materials pass the No. 200 sieve, and 2.5 to 31 percent of these materials are finer than 2 μ.

As shown in Figure 3, the grain size curves generally formed a band with consistent shape with the exception of TP-24. TP-24 was excavated in the existing borrow pit area, where approximately 40 feet of overburden has already been excavated. This material is much coarser and contains a substantial amount of weathered rock. For purposes of the soil liner mix design study, this material is not considered representative of the near surface materials and was not considered further. TP-23 also was located in the borrow pit area but closer to the entrance where the ground elevation is within 15 feet of the original grade, and is therefore considered representative of the near-surface site soils.

The curves for TP-1 and TP-13 are similar, and slightly removed from the other curves. TP-13 was selected as one of the coarsest samples for further testing. Though TP-1 represented the other coarsest sample, it was felt that one of the curves closer to the cluster of other curves would be more representative of the site soils. Thus, TP-2 was selected as the other



The Woods Road SWMF
Grain Size Summary
Figure 3

Table 2
Summary of Index Test Results

Test Pit	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10	TP11	TP12
Sieve Size	Percent Passing											
2"	100	100	100	100	100	100	100	100	100	100	100	100
1"	92.6	100	100	100	100	100	100	89.6	100	100	100	100
3/4"	86.9	94.3	100	93	100	100	94.7	89.6	94.6	93.5	85.2	100
3/8"	74.6	84	89.6	82.4	91.3	93.3	89.1	89.1	88.2	88.5	78.7	87.5
#4	68.1	74.3	82.6	78.6	88.5	88.7	85.9	85.5	85.8	85	73.2	81.3
#10	65.2	68.7	78.1	74.7	86.6	84.9	82.4	83.1	83.2	81.3	68.7	77.1
#20	58.1	64.4	72.9	70.7	83.8	80	78.4	80.1	80.3	76.9	65.1	72.4
#40	53.4	61.4	69	66.9	80.5	76.3	74.7	77.5	77.6	73.2	62.2	68.5
#60	51.2	59	66.5	64.1	77.8	74.7	72	75.8	75.4	70	57.9	66.2
#100	46.5	55	62.6	60	74.4	71	68.1	72.7	71.5	65.1	48.8	59.6
#200	38.6	47.3	53.7	51.1	65.3	63.7	59.8	64.6	60.8	54.2	47.7	50.1
.02 mm	19	28.5	33	33	45	43	35	42	35	31.5	37	39.5
.002 mm	5.5	12.5	8.5	14	15.5	13	11.5	14.5	11	9.5	11	12
Liquid Limit	37	40	40	41	41	43	43	40	44	37	36	33
Plastic Limit	26	29	29	29	29	31	27	27	24	25	25	25
Plasticity Index	11	11	11	12	12	12	16	13	20	12	11	8
USCS Classification	SM	SM	ML	ML	ML	ML	ML	ML	CL	ML	SM	ML

Test Pit	TP13	TP14	TP15	TP16	TP17	TP18	TP19	TP20	TP21	TP22	TP23	TP24
Sieve Size	Percent Passing											
2"	100	100	100	100	100	100	100	100	100	100	100	100
1"	100	100	100	100	100	100	100	100	100	100	100	90.7
3/4"	88.4	91.7	95.2	100	100	92.8	100	96.9	93.3	100	100	90.7
3/8"	80.2	86.9	95.2	84.1	98.3	84.3	94.2	82	86.5	96.7	89.8	52.6
#4	70.5	81.9	92.8	75	93.5	80.4	87.6	78.2	82.1	93.9	83.7	40.6
#10	64.7	78.4	92	70.9	88.7	78.2	84	76.3	78.1	91.7	78.5	30.5
#20	58.9	74.5	90	65.4	83.1	73.8	79.6	73.2	74.1	87.3	73.7	23.1
#40	54.5	71.6	86.5	61.7	78.3	69.4	75.3	70.6	70	82.9	69.5	18.7
#60	51.1	69.3	83.5	59.2	74.8	66.5	71.7	67.9	66.6	79.7	65.8	16.9
#100	46.2	65.1	79.5	54.4	69	61.3	66	62.6	61.6	74.2	59.9	13.5
#200	38.4	56	69.6	43.8	57.2	52.7	55.5	52.2	52.5	62.9	49.1	10.5
.02"	30	48	56.5	38.5	43	47.5	51.5	40	47	57	41	7
.002"	8.5	18.5	25	10.5	18	31	17.5	10	13	18.5	12	2.5
Liquid Limit	34	42	40	33	41	53	39	38	39	41	38	29
Plastic Limit	24	27	26	24	27	34	27	24	24	35	26	NP
Plasticity Index	10	15	14	9	14	19	12	14	15	6	12	NP
USCS Classification	SM	ML	ML	SM	ML	MH	ML	CL	CL	ML	SM	GP-GM

"coarsest" sample. Similarly, the finest sample selected was TP-5, as it appeared to be relatively fine, but also representative of the other soil samples. Figure 4 highlights the samples selected for further testing. The characterization laboratory test data are presented in Attachment C.

Phase 2–Percent Bentonite Versus Hydraulic Conductivity

Laboratory Testing

The second phase of laboratory testing investigated the relationship between the percent bentonite added and hydraulic conductivity achieved on the one finest and two coarsest samples selected in the characterization testing. Trial mixes were prepared using materials passing the 3/4-inch sieve screen from each of the three samples. Material not passing the 3/4-inch sieve constituted from zero to 15 percent of the samples, by weight in general. This oversized material also will be screened out during construction of the liner system.

Three application rates of bentonite of 3, 5, and 6.5 percent by dry weight were prepared. Samples were recompacted to 95 percent of the maximum dry density as determined by ASTM D698 at the optimum moisture content and then tested for hydraulic conductivity in accordance with ASTM D5084. Grain size and Atterberg Limits testing were also performed to help characterize the bentonite-amended soil samples.

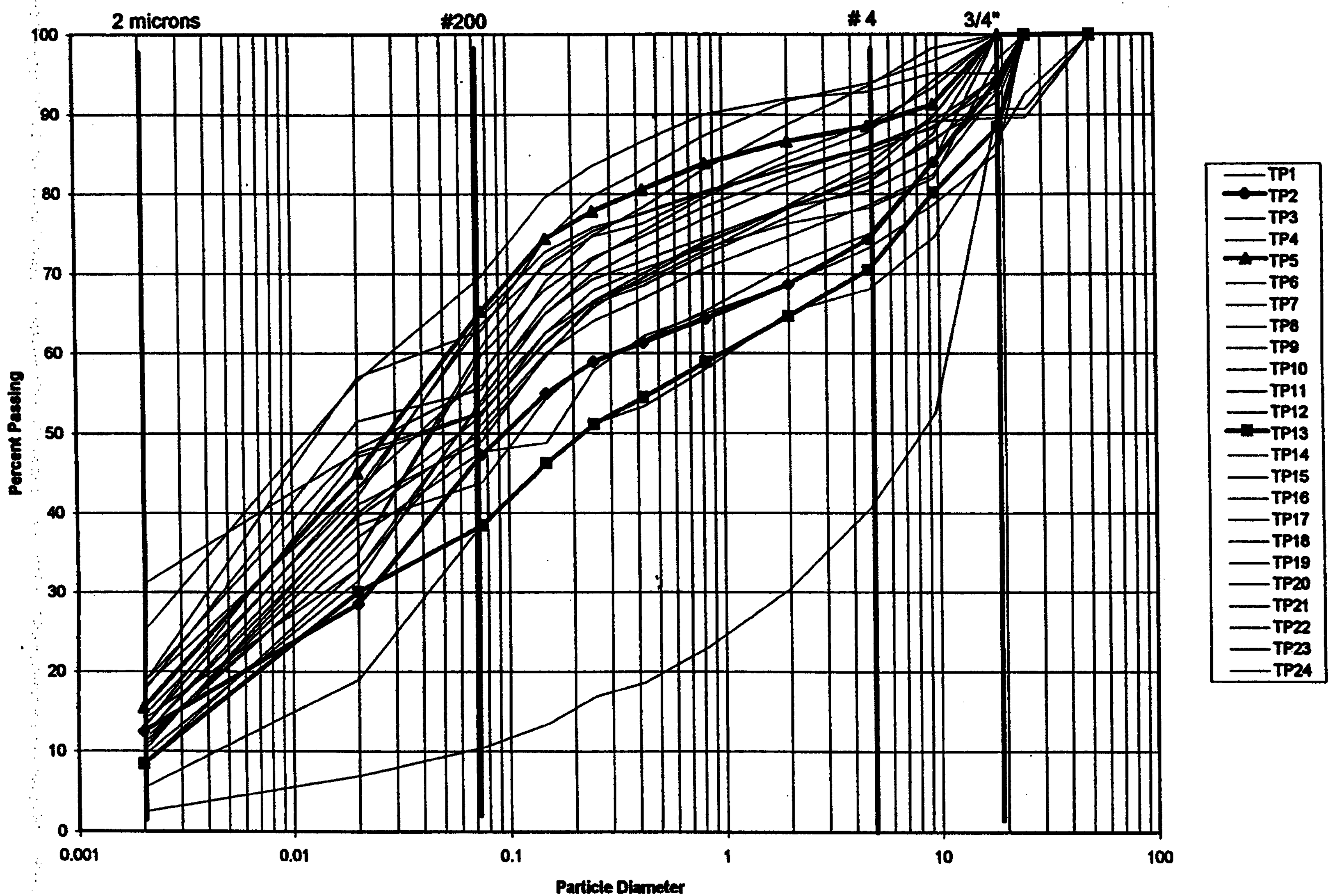
Baroid BENSEAL semigranular Grouting Bentonite was used in the soil mix design laboratory testing. Additional information on the bentonite is presented in Attachment D.

Laboratory Results

The results of this phase, studying the relationship between percent bentonite and hydraulic conductivity on the finest sample, TP-5, and two coarsest samples, TP-2 and TP-13, are summarized in Table 3. Trial mixes were prepared using materials from each of the three samples with bentonite application rates of 3, 5, and 6.5 percent by dry weight. These results indicate decreasing values of hydraulic conductivity as the percent bentonite is increased from 3 to 6.5 percent as shown in Figure 5. This relationship appears to be linear for sample TP-2 but curved slightly upward for samples TP-5 and TP-13, indicating that increasing the bentonite application rate decreases the hydraulic conductivity of the material, but at a decreasing rate.

At 6.5 percent bentonite, all three samples have a permeability less than the 1 x 10^{-7} cm/s value required by regulation. However, a target laboratory value in the range of 5 x 10^{-8} cm/s was selected to ensure that resultant hydraulic conductivity's of less than the 1 x 10^{-7} cm/s were achieved. Based on this, a bentonite application rate was determined by linearly extrapolating the test results at 5 and 6.5 percent bentonite to the laboratory target value for all samples. Further testing was performed on the samples using a bentonite application rate of 7 percent.

The percent bentonite versus hydraulic conductivity laboratory test data are presented in Attachment E.



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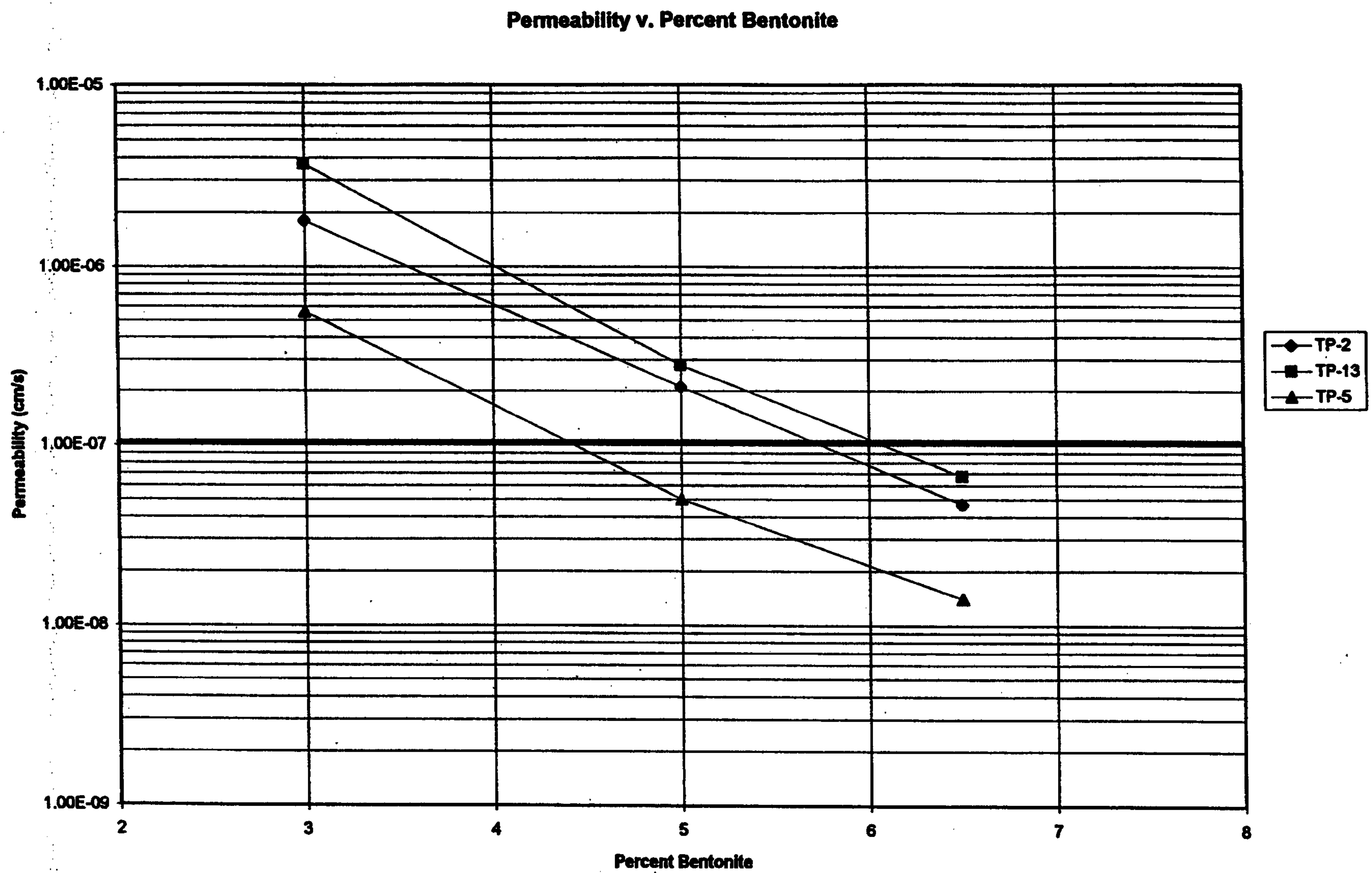
The Woods Road SWMF
Samples Selected for Further Testing
Figure 4



The Woods Road SWMF
Permeability vs. Percent Bentonite
Figure 5

Table 3
Summary of Phase 2 Testing

	Coarse Samples		Fine Sample
***In Situ* Soil**	**TP-2**	**TP-13**	**TP-5**
Liquid Limit	40	34	41
Plastic Limit	29	24	29
Plasticity Index	11	10	12
Percent finer than #200 sieve	47.3	38.4	65.3
Classification	SM	SM	ML
Percent Bentonite	**3.0**	**3.0**	**3.0**
Maximum Dry Density (pcf)	104.9	109.0	115.2
Optimum Moisture (%)	20.7	18.0	18.0
Hydraulic Conductivity at 95% Relative Compaction (cm/s)	1.8×10^{-6}	3.7×10^{-6}	5.6×10^{-6}
Liquid Limit	45	39	47
Plastic Limit	23	21	21
Plasticity Index	22	18	26
Percent finer than #200 sieve	51.5	43.5	66.8
Percent Bentonite	**5.0**	**5.0**	**5.0**
Maximum Dry Density (pcf)	102.7	105.9	112.6
Optimum Moisture (%)	21.5	19.5	18.4
Hydraulic Conductivity at 95% Relative Compaction (cm/s)	2.1×10^{-7}	2.8×10^{-7}	5.0×10^{-8}
Liquid Limit	52	46	59
Plastic Limit	23	22	23
Plasticity Index	29	24	36
Percent finer than #200 sieve	52.0	42.6	70.5
Percent Bentonite	**6.5**	**6.5**	**6.5**
Maximum Dry Density (pcf)	101.5	104.1	110.8
Optimum Moisture (%)	22.8	21.3	17.1
Hydraulic Conductivity at 95% Relative Compaction (cm/s)	4.7×10^{-8}	6.7×10^{-8}	1.4×10^{-8}
Liquid Limit	56	51	62
Plastic Limit	23	23	24
Plasticity Index	33	28	38
Percent finer than #200 sieve	55.8	44.7	71.0
Note: All hydraulic conductivity tests performed on laboratory recompacted samples			

Phase 3–Moisture-Density Versus Hydraulic Conductivity

Based on the findings of the relationship between percent bentonite and hydraulic conductivity, a fixed bentonite application rate of 7 percent was selected to further evaluate the two coarsest samples identified above. Trial mixes were prepared from the minus 3/4-inch fraction of the two coarsest samples at various moisture contents and densities to develop an envelope of conditions for acceptable performance. Recompacted samples for each trial mix were prepared as summarized in Table 4 and tested for hydraulic conductivity in accordance with ASTM D5084. Grain size and Atterberg Limits tests were also performed to help characterize the bentonite-amended soil samples.

Table 4
Summary of Combinations of Moisture Content and Density

Moisture Content (%)	Density[1] (%)
+2	92
-1	95
Optimum	95
+2	95
-1	98

[1]Percent of maximum dry density as determined by ASTM D698.

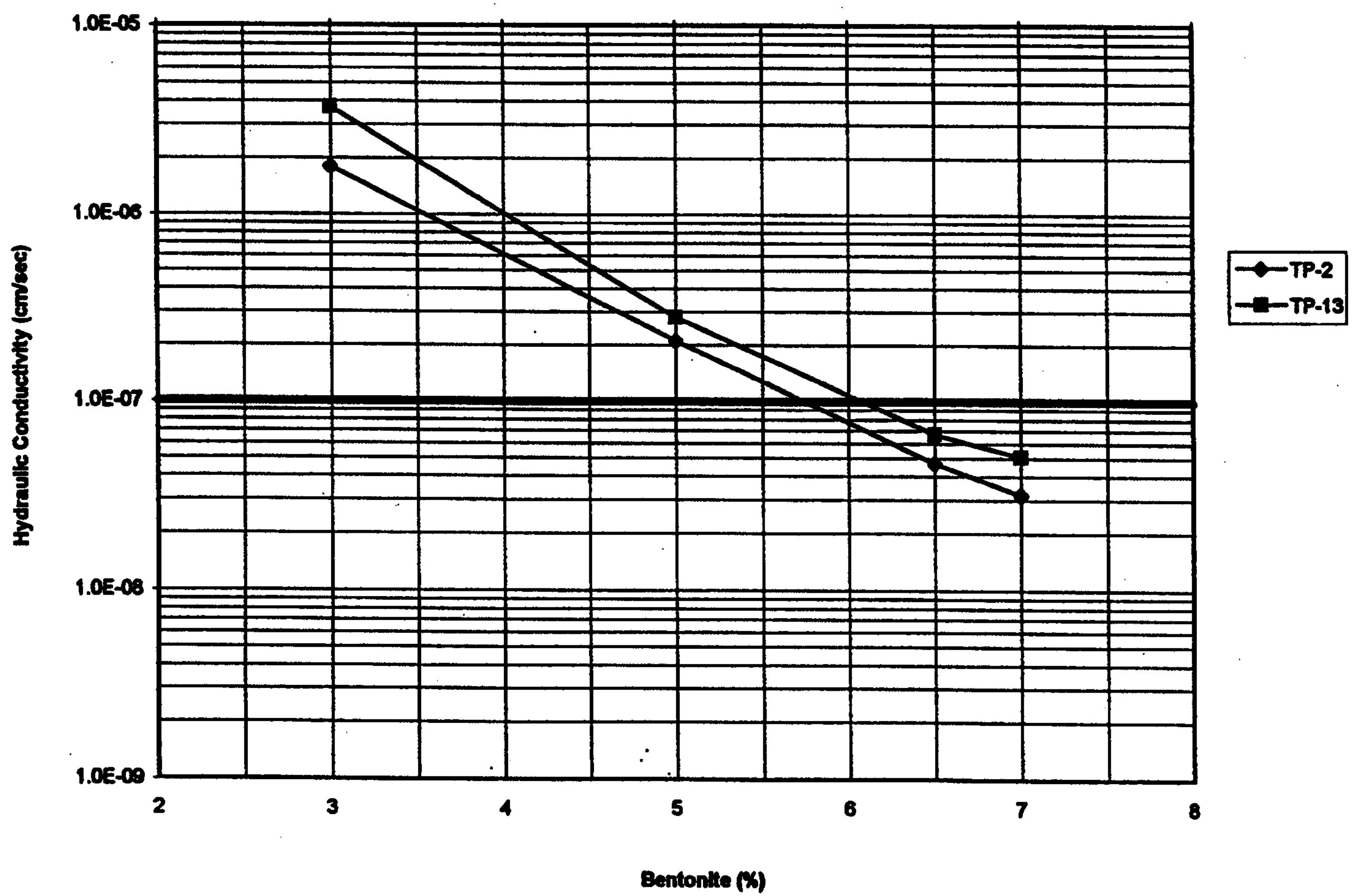
Laboratory Results

The variations of moisture content and relative compaction and resultant hydraulic conductivity values are summarized in Table 5. Hydraulic conductivity testing results indicate that all of the samples had hydraulic conductivities less than 5.4×10^{-8} cm/sec. Figure 6 plots the percent bentonite versus hydraulic conductivity for the two coarse samples and Figure 7 graphically presents the hydraulic conductivity results as they relate to the moisture density curves for samples from test pits TP-2 and TP-13.

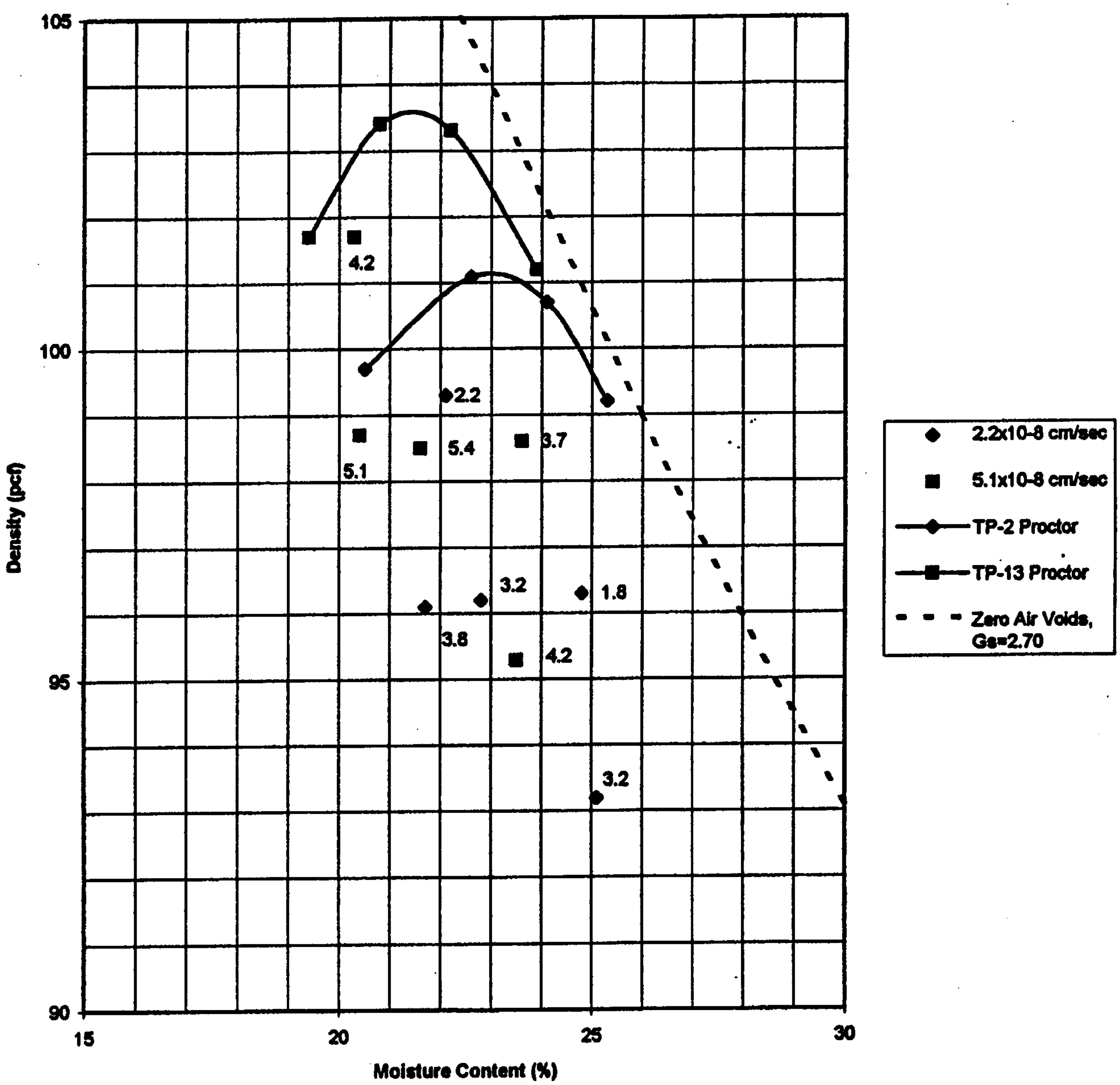
As seen in Table 5, the 7 percent bentonite mix yielded acceptable hydraulic conductivity values in the range of 5×10^{-8} cm/s for both samples under all three moisture conditions at 95 percent relative compaction. This suggests that with proper field control, the maximum allowable permeability of 1×10^{-7} cm/s is probably achievable with this mix. In order to attempt to define the limits of the acceptable permeability results (e.g., the highest moisture content giving acceptable results or the lowest compaction giving acceptable results), two more tests were performed on each sample with more extreme conditions of 98 percent relative compaction at 1 percent dry of optimum moisture content and 92 percent relative compaction at 2 percent wet of optimum. These tests also fell below the maximum permeability target of 5×10^{-8}.

The moisture-density versus hydraulic conductivity laboratory test data are presented in Attachment F.

Table 5 Summary of Phase 3 Testing		
	Coarse Samples	
	TP-2	TP-13
Percent Bentonite	7.0	7.0
Liquid Limit	58	52
Plastic Limit	25	24
Plasticity Index	33	28
Percent finer than #200 sieve	54.5	44.6
Optimum Moisture (%)	101.2	103.8
	23.0	21.5
Hydraulic Conductivity at 95% Relative Compaction Optimum Moisture Content (cm/s)	3.2×10^{-8}	5.1×10^{-8}
Dry Density (pcf)	96.2	98.5
Moisture Content (%)	22.8	21.6
Hydraulic Conductivity at 95% Relative Compaction Optimum Moisture Content minus 1% (cm/s)	3.8×10^{-8}	5.4×10^{-8}
Dry Density (pcf)	96.1	98.7
Moisture Content (%)	21.7	20.4
Hydraulic Conductivity at 95% Relative Compaction Optimum Moisture Content plus 2% (cm/s)	1.9×10^{-8}	3.7×10^{-8}
Dry Density (pcf)	96.3	98.6
Moisture Content (%)	24.8	23.6
Hydraulic Conductivity at 98% Relative Compaction Optimum Moisture Content minus 1% (cm/s)	2.2×10^{-8}	4.4×10^{-8}
Dry Density (pcf)	99.3	101.7
Moisture Content (%)	22.1	20.3
Hydraulic Conductivity at 92% Relative Compaction Optimum Moisture Content plus 2% (cm/s)	3.2×10^{-8}	4.2×10^{-8}
Dry Density (pcf)	93.2	95.4
Moisture Content (%)	25.1	23.5
Note: All hydraulic conductivity tests performed on laboratory recompacted samples.		



The Woods Road SWMF
Percent Bentonite Versus Hydraulic Conductivity
Figure 6



The Woods Road SWMF
Moisture Density Variability
Figure 7

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Phase 4–Variability Performance

Laboratory Testing

In the final phase of laboratory testing, the results developed on the two coarsest samples were tested on four other samples to determine the effects of the variability of the samples on the results obtained. The four samples tested were composited from test pits representing Phases I through IV of the proposed landfill development. The composite samples were prepared by combining equal parts of material passing the 3/4-inch screen by dry weight from each test pit sample, as summarized in Table 6 below. Each of the samples was compacted to 95 percent relative compaction at 1 percent dry, and 2 percent wet of optimum moisture content and tested for hydraulic conductivity, particle size and Atterberg limits.

Table 6
Summary of Composite Samples

Composite Sample No.	Test Pits
CS-I	TP-4, TP-5, TP-8
CS-II	TP-6, TP-7, TP-11
CS-III	TP-9, TP-10, TP-14, TP-15
CS-IV	TP-16, TP-17, TP-18, TP-21

Laboratory Results

The final phase of laboratory testing consisted of preparing 4 composite samples to determine the effects of material variability on the results of recompacted hydraulic conductivity testing. Trial mixes of composite samples CS-I, CS-II, CS-III, and CS-IV were prepared by mixing each sample with 7 percent bentonite by dry weight at moisture contents 1 percent dry of optimum moisture content, optimum moisture content, and 2 percent wet of optimum moisture content. Recompacted samples for each trial mix were prepared at 95 percent relative compaction and tested for hydraulic conductivity. Table 7 summarizes the results from Phase 4 of the testing program. As shown, all of the composite samples met the maximum permeability requirement at a 7 percent bentonite amendment rate and 95 percent compaction. Figure 8 presents moisture density and hydraulic conductivity results for the four composite samples and Figure 9 summarizes hydraulic conductivity results for all samples tested with 7 percent bentonite.

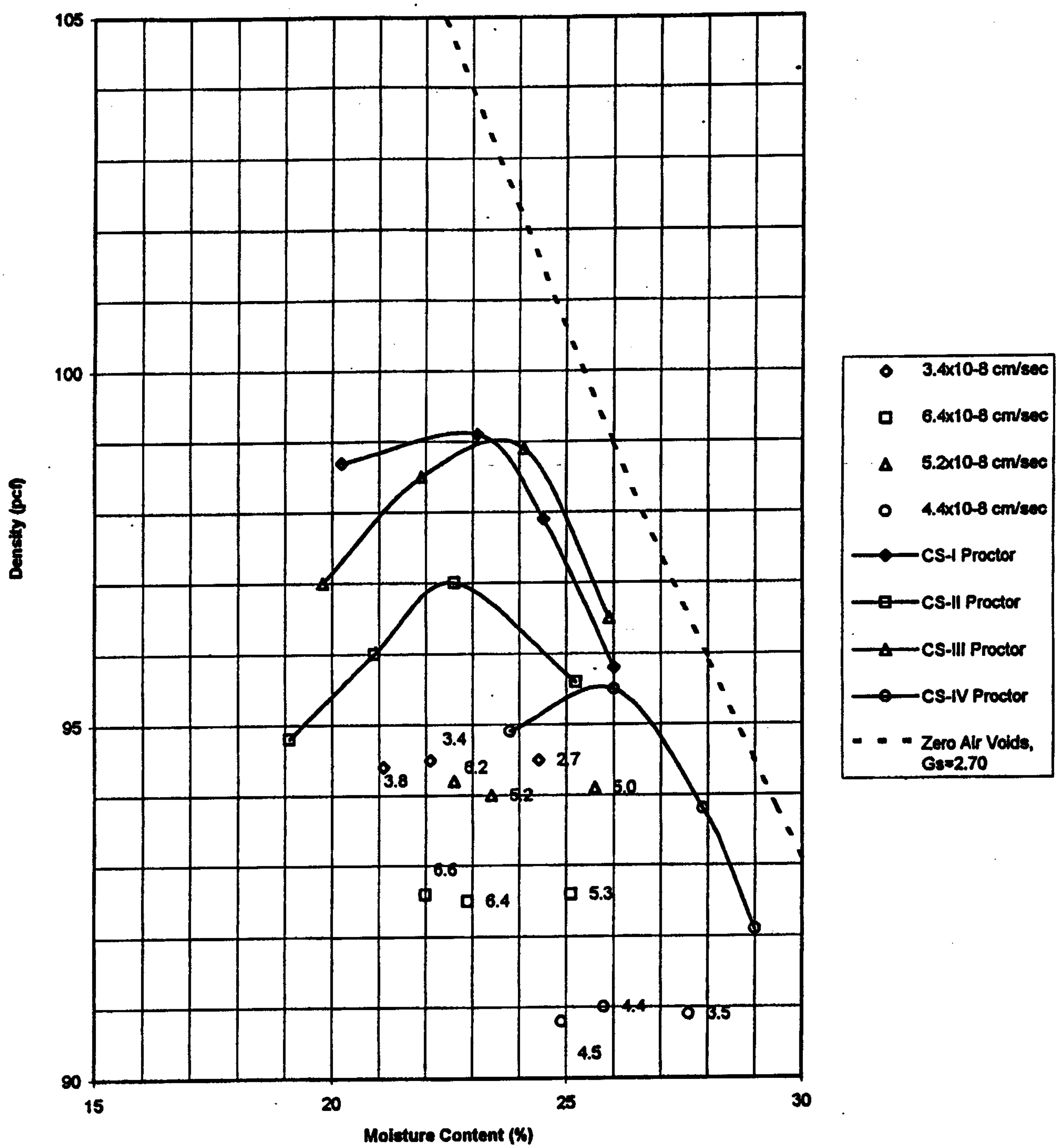
The variability performance laboratory test data are presented in Attachment G.

Recommendations

Soil Bentonite Mix

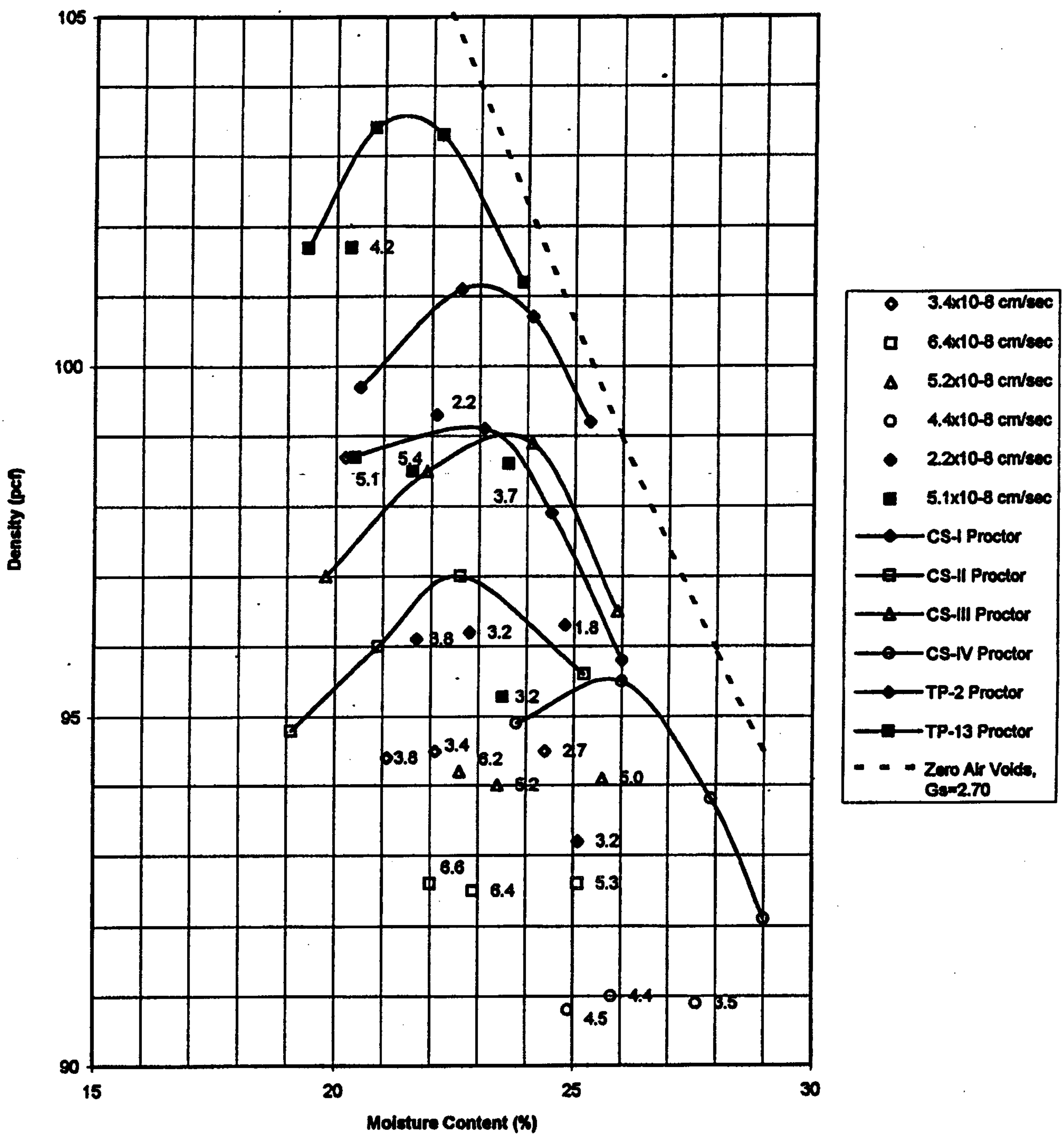
Based on the results of the laboratory testing done to date, CH2M HILL recommends that a 7 percent by dry weight application rate of bentonite be used to ensure a maximum field

Table 7 Summary of Phase 4 Testing				
	Composite Samples			
	CS-I	CS-II	CS-III	CS-IV
Test Pits Included	4, 5, 8	6, 7, 11	9, 10, 14, 15	16, 17, 18, 21
Percent Bentonite	7.0	7.0	7.0	7.0
Liquid Limit	81	71	76	77
Plastic Limit	23	28	28	25
Plasticity Index	58	43	48	52
Percent finer than #200 sieve	58.6	54.7	65.3	62.6
Specific Gravity	2.75	2.76	2.75	2.78
Maximum Dry Density (pcf)	99.4	97.1	99.0	95.6
Optimum Moisture (%)	22.2	23.2	23.5	25.8
Hydraulic Conductivity at 95% Relative Compaction Optimum Moisture Content (cm/s)	3.4×10^{-8}	6.4×10^{-8}	5.2×10^{-8}	4.4×10^{-8}
Dry Density (pcf)	94.5	92.5	94.0	91.0
Moisture Content (%)	22.1	22.9	23.4	25.8
Hydraulic Conductivity at 95% Relative Compaction Optimum Moisture Content minus 1% (cm/s)	3.8×10^{-8}	6.6×10^{-8}	6.2×10^{-8}	4.5×10^{-8}
Dry Density (pcf)	94.4	92.6	94.2	90.8
Moisture Content (%)	21.1	22.0	22.6	24.9
Hydraulic Conductivity at 95% Relative Compaction Optimum Moisture Content plus 2% (cm/s)	2.7×10^{-8}	5.3×10^{-8}	5.0×10^{-8}	3.5×10^{-8}
Dry Density (pcf)	94.5	92.6	94.1	90.9
Moisture Content (%)	24.4	25.1	25.6	27.6
Note: All hydraulic conductivity tests performed on laboratory recompacted samples.				



The Woods Road SWMF
Material Variability Testing
Figure 8

CH2M HILL



The Woods Road SWMF
Summary of Results at 7% Bentonite
Figure 9

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permeability of 1×10^{-7} cm/s. To provide a uniform mix of soil, water, and bentonite, a pugmill mixing operation is recommended.

The results of the laboratory testing should be verified under field conditions by constructing a test pad. Recommendations for the test pad are summarized below and detailed in the specification Section 2245 TEST PAD, included as Attachment H to this technical memorandum.

Test Pad

Size and Shape

It is recommended that the test pad be approximately 40 feet wide by 100 feet long. The pad will be divided into two 20-foot-wide lanes. The 20-foot by 100-foot lane will ensure that construction equipment can effectively simulate actual field conditions while reducing edge effects. The test pad will be located near the northeast corner of the proposed landfill, as shown on Figure 2.

Moisture Content

It is recommended that a different moisture condition be tested in each lane. Lane A should be compacted between optimum moisture content and optimum moisture content minus 1 percent. Lane B should be compacted between optimum moisture content plus 1 and optimum moisture content plus 2. This will allow field verification of the range of moisture contents tested in the laboratory and to be allowed in actual construction.

Compactive Effort

It is recommended that the test pad be constructed in four 6-inch compacted lifts. Each lift should be compacted to 95 percent relative compaction based on ASTM D698. The number of compactor passes for the first one or two lifts in each lane will be counted and the compaction will be tested in the field after 2, 4, 6, and 8 passes in order to determine the actual number of passes required to achieve 95 percent relative compaction. This information will be used as guidance in subsequent lifts, though each lift will continue to be tested to verify compaction and moisture content.

Equipment

Equipment anticipated to be used to construct the landfill should be used construct the test pad. Typical equipment may include excavators or bulldozers to excavate the soil, pans or dump trucks to haul the soil, a loader for the screening and pugmill operations, a sheepsfoot compactor, a water truck for moisture control, a discer or rake to scarify the surfaces, and a smooth drum roller to seal the surface. The soil bentonite mixing will be done with a pugmill and a screen will be used to remove oversize particles prior to mixing.

Testing

It is our understanding that testing will be done the by the County's geotechnical consultant, Law Engineering. Testing should be done before test pad construction begins in order to establish preliminary values of maximum dry density and optimum moisture content for comparison with field testing. Testing also should be done during test pad construction for quality control of the bentonite mixing process and compaction. Finally, testing of the finished test pad should be performed to determine the hydraulic conductivity and shear strength values of the constructed bentonite-amended soil test pad. Table 8 summarizes proposed testing for the test pad.

Limitations

This report has been prepared for the exclusive use of the County of Loudoun for specific application to the Woods Road SWMF in accordance with generally accepted geotechnical engineering practice. No other warranty, express or implied, is made.

The analyses and recommendations contained in this report are based on the data obtained from test pits. Test pits indicate subsurface conditions only at specific locations and times, and only to the depths penetrated. They do not necessarily reflect strata variations that may exist between such locations. The dispersed test pits represent a small sampling of the entire soil volume. Although fragmentary, design guidelines have been developed from these data. If variations in subsurface condition from those described are noted during construction, recommendations in this report must be re-evaluated.

In the event that any changes in the nature, design, or location of the facilities are planned, the conclusions and recommendations contained in this report should not be considered valid unless the changes are reviewed and conclusions of this report modified or verified in writing by CH2M HILL. CH2M HILL is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or reuse of the subsurface data or engineering analyses without the express written authorization of CH2M HILL.

Table 8
Proposed Test Pad Testing Program

Test/Sample	Method	Quantity	Description
Testing Before Test Pad Construction - Borrow Soil			
Atterberg Limits	ASTM D4318	1	Bulk composite soil sample from a depth of 1 to 8 feet below the ground surface taken from the designated borrow area.
Particle Size	ASTM D422	1	Same as above
Testing Before Test Pad Construction - Bentonite-amended Soil			
Moisture Density	ASTM D698	1	Sample of soil to be used in test pad construction amended with 7% bentonite[1]
Atterberg Limits	ASTM D4318	1	Sample of soil to be used in test pad construction amended with 7% bentonite[1]
Particle Size	ASTM D422	1	Sample of soil to be used in test pad construction amended with 7% bentonite[1]
Testing During and After Test Pad Construction			
Moisture Density	ASTM D698	2	Sample of bentonite-amended soil from pugmill operation; after 24 cy processed and after 300 cy processed.
Thin-walled Tube Samples	--	4	Two samples from Lanes A and B at completion of test pad construction.
Atterberg Limits	ASTM D4318	4	One test on each thin-walled tube sample.
Particle Size	ASTM D422	4	One test on each thin-walled tube sample.
Hydraulic Conductivity	ASTM D5084	4	One test on each thin-walled tube sample.
Two-stage Borehole (Boutwell) Permeameter	Per ASCE J. of Geotechnical Engineering, Volume 115, No. 9, September, 1989	2	One test per lane.
In-place Density and Water Content Measurement by Nuclear Methods	ASTM D2922 and ASTM D3017	To be determined	At three locations in each lane after 2, 4, 6, and 8 compactor passes, or until 95% compaction is achieved for each lift.
Consolidated Undrained Shear Strength[2]	ASTM D4767	2	One test on each thin-walled tube sample.
Interface Friction[3]	ASTM D5321	2	One test on each thin-walled tube sample.

Notes:
[1] Bentonite to be provided by the test pad contractor.
[2] Each test will be conducted at 2 confining stresses that approximate initial and final waste thickness conditions.
[3] Bentonite-amended soil and 60-mil textured HDPE.

Attachment A
Test Pit Logs

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PROJECT NUMBER	TEST PIT NUMBER
ENE40180.DS.TP	TP-1 SHEET 1 OF 1

TEST PIT LOG

PROJECT Woods Road Landfill **LOCATION** 166' N of L7, 157' E of L7 **LOGGER** A. Estabrook

ELEVATION 380 feet (approx.) **CONTRACTOR** Leo Construction, Lenah, VA

EXCAVATION EQUIPMENT Case 580K Backhoe, 18" bucket **DATE EXCAVATED** 3/6/95

WATER LEVEL AND DATE None encountered **APPROX. DIMENSIONS: Length** 11.5 ft. **Width** 1.5 ft. **Max Depth** 10 ft.

DEPTH BELOW SURFACE (FT)	SAMPLE		SOIL DESCRIPTION	COMMENTS
	INTERVAL	NUMBER AND TYPE	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DIFFICULTY IN EXCAVATION, RUNNING GRAVEL CONDITION, COLLAPSE OF WALLS, SAND HEAVE DEBRIS ENCOUNTERED, WATER SEEPAGE GRADATIONAL CONTACTS, TESTS, INSTRUMENTATION
			SILTY SAND (SM), brown, moist, loose, with roots and organics TOPSOIL	
	2.0		CLAYEY SAND (SC), reddish brown, moist, medium dense	
			SANDY LEAN CLAY (CL), reddish brown, moist, firm, mixed with SILT (ML), mottled yellow, gray and black, moist, firm and occasional rocks 2"-4" typically	Collected composite sample from 2' to 10'
5.0		1-C		
				More rocks below 8' appox.
10.0	10.0		END TEST PIT @ 10 FEET	
15.0				

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PROJECT NUMBER	TEST PIT NUMBER
ENF40160.DS.TP	TP-2 SHEET 1 OF 1

TEST PIT LOG

PROJECT Woods Road Landfill LOCATION 90' N of L6, 36' E of L6 LOGGER A. Estabrook

ELEVATION 402 feet (approx.) CONTRACTOR Leo Construction, Lenah, VA

EXCAVATION EQUIPMENT Case 580K Backhoe, 18" bucket DATE EXCAVATED 3/6/95

WATER LEVEL AND DATE None encountered APPROX. DIMENSIONS: Length 12 ft. Width 1.5 ft. Max Depth 11.5 ft.

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DIFFICULTY IN EXCAVATION, RUNNING GRAVEL CONDITION, COLLAPSE OF WALLS, SAND HEAVE DEBRIS ENCOUNTERED, WATER SEEPAGE GRADATIONAL CONTACTS, TESTS, INSTRUMENTATION
			SILTY SAND (SM), brown, moist, loose, with roots and organics TOPSOIL	
	3.0		SILTY SAND (SM), orangish brown, moist, medium dense	Collected composite sample from 3' to 10'approx.
5.0		2-C	SANDY LEAN CLAY (CL), reddish brown, moist, firm, mottled with yellow, gray and black SILT (ML), moist, firm, occasional rocks up to 8" max. size	
10.0	10.0			
			END TEST PIT @ 11.5 FEET	
15.0				

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PROJECT NUMBER	TEST PIT NUMBER	
ENE40160.DS.TP	TP-3	SHEET 1 OF 1

TEST PIT LOG

PROJECT Woods Road Landfill **LOCATION** Between L6 and L12, 26' E of road **LOGGER** A. Estabrook

ELEVATION 370 feet (approx.) **CONTRACTOR** Leo Construction, Lenah, VA

EXCAVATION EQUIPMENT Case 580K Backhoe, 18" bucket **DATE EXCAVATED** 3/6/95

WATER LEVEL AND DATE None encountered **APPROX. DIMENSIONS: Length** 11 ft. **Width** 1.5 ft. **Max Depth** 11.5 ft.

DEPTH BELOW SURFACE (FT)	SAMPLE		SOIL DESCRIPTION	COMMENTS
	INTERVAL	NUMBER AND TYPE	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DIFFICULTY IN EXCAVATION, RUNNING GRAVEL CONDITION, COLLAPSE OF WALLS, SAND HEAVE DEBRIS ENCOUNTERED, WATER SEEPAGE GRADATIONAL CONTACTS, TESTS, INSTRUMENTATION
			SILTY SAND (SM), brown, moist, loose, with roots and organics TOPSOIL	Collected composite sample from 4' to 11'approx.
			CLAYEY SAND (SC), reddish brown, moist, medium dense	
	4.0			
			SANDY LEAN CLAY (CL), reddish brown, moist, firm, with lenses of SILT (ML), yellow gray, orange, pink and black, moist, firm, few rocks	Very gradual transition @ 4' approx.
5.0				
		3-C		
10.0				
	11.0			
			END TEST PIT @ 11.5 FEET	
15.0				

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PROJECT NUMBER	TEST PIT NUMBER	
ENE40160.DS.TP	TP-4	SHEET 1 OF 1

TEST PIT LOG

PROJECT Woods Road Landfill **LOCATION** Between L6 and L12, 26' E of road **LOGGER** A. Estabrook
ELEVATION 394 feet (approx.) **CONTRACTOR** Leo Construction, Lenah, VA
EXCAVATION EQUIPMENT Case 580K Backhoe, 18" bucket **DATE EXCAVATED** 3/6/95
WATER LEVEL AND DATE None encountered **APPROX. DIMENSIONS: Length** 11 ft. **Width** 1.5 ft. **Max Depth** 10 ft.

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SOIL DESCRIPTION: SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS: DIFFICULTY IN EXCAVATION, RUNNING GRAVEL CONDITION, COLLAPSE OF WALLS, SAND HEAVE DEBRIS ENCOUNTERED, WATER SEEPAGE GRADATIONAL CONTACTS, TESTS, INSTRUMENTATION
			SILTY SAND (SM), brown, moist, loose, with roots and organics TOPSOIL	Collected composite sample from 2' to 10'
	2.0		CLAYEY SAND (SC), reddish brown, moist, medium dense	
5.0		4-C	SANDY LEAN CLAY (CL), reddish brown, moist, firm, mixed with SILT (ML), mottled gray and yellow, moist, firm, and occasional rocks	
10.0	10.0		END TEST PIT @ 10.0 FEET	
15.0				

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PROJECT NUMBER	TEST PIT NUMBER
ENF40160.DS.TP	TP-5 SHEET 1 OF 1

TEST PIT LOG

PROJECT Woods Road Landfill **LOCATION** Between L5 and L11, 100' W of house **LOGGER** A. Estabrook

ELEVATION 376 feet (approx.) **CONTRACTOR** Leo Construction, Lenah, VA

EXCAVATION EQUIPMENT Case 580K Backhoe, 18" bucket **DATE EXCAVATED** 3/6/95

WATER LEVEL AND DATE None encountered **APPROX. DIMENSIONS: Length** 12 ft. **Width** 1.5 ft. **Max Depth** 11.5 ft.

DEPTH BELOW SURFACE (FT)	SAMPLE		SOIL DESCRIPTION	COMMENTS
	INTERVAL	NUMBER AND TYPE	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	DIFFICULTY IN EXCAVATION, RUNNING GRAVEL CONDITION, COLLAPSE OF WALLS, SAND HEAVE DEBRIS ENCOUNTERED, WATER SEEPAGE GRADATIONAL CONTACTS, TESTS, INSTRUMENTATION
			SILTY SAND (SM), brown, moist, loose, with roots and organics TOPSOIL	Collected composite sample from 2.5' to 11.5'
	2.5		CLAYEY SAND (SC), reddish brown, moist, dense	
5.0		5-C	SANDY LEAN CLAY WITH GRAVEL (CL), dark reddish brown, moist, firm with occasional lenses of SILT (ML), mottled yellow and gray, gravel is 4"-6" typ.	
10.0	11.5			
			END TEST PIT @ 11.5 FEET	
15.0				

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PROJECT NUMBER	TEST PIT NUMBER
ENF40160.DS.TP	TP-8 SHEET 1 OF 1

TEST PIT LOG

PROJECT Woods Road Landfill LOCATION 70' SW of L11 LOGGER A. Estabrook
ELEVATION 368 feet (approx.) CONTRACTOR Leo Construction, Lenah, VA
EXCAVATION EQUIPMENT Case 580K Backhoe, 18" bucket DATE EXCAVATED 3/6/95
WATER LEVEL AND DATE None encountered APPROX. DIMENSIONS: Length 10 ft. Width 1.5 ft. Max Depth 11 ft.

DEPTH BELOW SURFACE (FT)	SAMPLE INTERVAL	SAMPLE NUMBER AND TYPE	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS DIFFICULTY IN EXCAVATION, RUNNING GRAVEL CONDITION, COLLAPSE OF WALLS, SAND HEAVE DEBRIS ENCOUNTERED, WATER SEEPAGE GRADATIONAL CONTACTS, TESTS, INSTRUMENTATION
			SILTY SAND (SM), brown, moist, loose with roots and organics (TOPSOIL)	
	2.0		CLAYEY SAND (SC), reddish brown, moist, medium dense, occasional rock	Collected composite sample from 2.0' to 10.0'
5.0		8-C	SANDY LEAN CLAY (CL), reddish brown, moist, firm, mottled with SILT (ML), white, black, yellow and gray, moist, firm, rocks 4"-6" typ.	Lense of gray cemented sand/weathered sandstone 4'-4.5' approx.
10.0	10.0			More rocks 10'-11'
			END TEST PIT @ 11.0 FEET	
15.0				

LAW ENGINEERING, INC.
Soil Data

PROJECT NAME: Loudoun County Landfill
PROJECT NUMBER: 482-11280-01
DATE: 3-15-95

Sieve Size	Sample TP-1	Sample TP-2	Sample TP-3	Sample TP-4	Sample TP-5	Sample TP-6
2	100.0					
1	92.6	100.0		100.0		
3/4	86.9	94.3	100.0	93.0	100.0	100.0
3/8	74.6	84.0	89.6	82.4	91.3	93.3
4	68.1	74.3	82.6	78.6	88.5	88.7
10	65.2	68.7	78.1	74.7	86.6	84.9
20	58.1	64.4	72.9	70.7	83.8	80.0
40	53.4	61.4	69.0	66.9	80.5	76.3
60	51.2	59.0	66.5	64.1	77.8	74.7
100	46.5	55.0	62.6	60.0	74.4	71.0
200	38.6	47.3	53.7	51.1	65.3	63.7
0.02 mm	19.0	28.5	33.0	33.0	45.0	43.0
0.002 mm	5.5	12.5	8.5	14.0	15.5	13.0

SAMPLE NO.	SAMPLE DEPTH (FT.)	SOIL CLASS.	NATURAL MOIST. (%)	LIQUID LIMIT (L.L)	PLASTIC LIMIT (P.L)	PLASTICITY INDEX (P.I.)
TP-1		SM		37	26	11
TP-2		SM		40	29	11
TP-3		ML		40	29	11
TP-4		ML		41	29	12
TP-5		ML		41	29	12
TP-6		ML		43	31	12

NOTES:

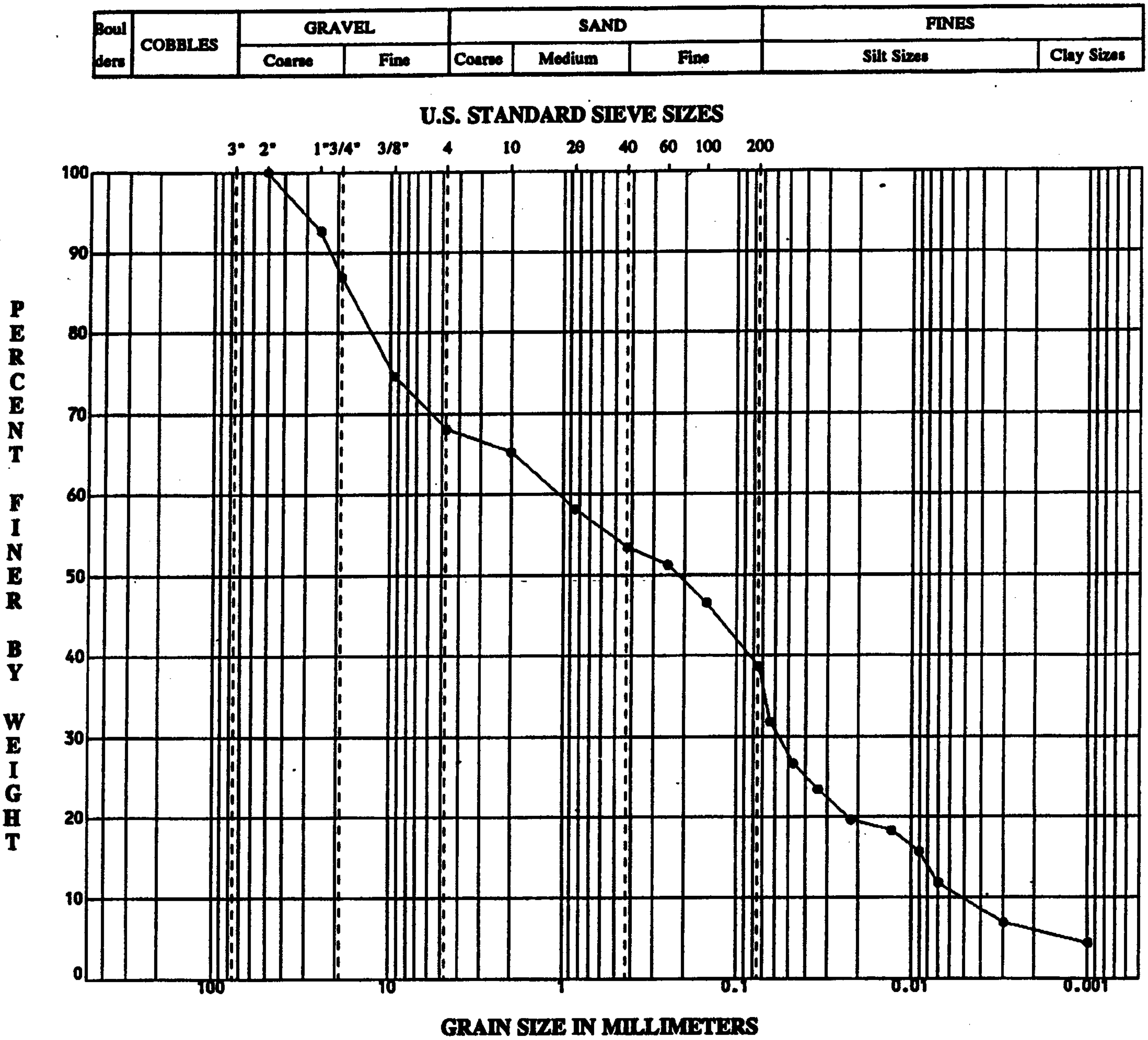
LAW ENGINEERING, INC.
Soil Data

PROJECT NAME: Loudoun County Landfill
PROJECT NUMBER: 482-11280-01
DATE: 3-15-95

Sieve Size	Sample TP-7	Sample TP-8	Sample TP-9	Sample TP-10	Sample TP-11	Sample TP-12
2		100.0				
1	100.0	89.6	100.0	100.0	100.0	
3/4	94.7	89.6	94.6	93.5	85.2	100.0
3/8	89.1	89.1	88.2	88.5	78.7	87.5
4	85.9	85.5	85.8	85.0	73.2	81.3
10	82.4	83.1	83.2	81.3	68.7	77.1
20	78.4	80.1	80.3	76.9	65.1	72.4
40	74.7	77.5	77.6	73.2	62.2	68.5
60	72.0	75.8	75.4	70.0	57.9	66.2
100	68.1	72.7	71.5	65.1	48.8	59.6
200	59.8	64.6	60.8	54.2	47.7	50.1
0.02 mm	35.0	42.0	35.0	31.5	37.0	39.5
0.002 mm	11.5	14.5	11.0	9.5	11.0	12.0

SAMPLE NO.	SAMPLE DEPTH (FT.)	SOIL CLASS.	NATURAL MOIST. (%)	LIQUID LIMIT (L.L.)	PLASTIC LIMIT (P.L.)	PLASTICITY INDEX (P.I.)
TP-7		ML		43	27	16
TP-8		ML		40	27	13
TP-9		CL		44	24	20
TP-10		ML		37	25	12
TP-11		SM		36	25	11
TP-12		ML		33	25	8

NOTES:



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
●						TP-1

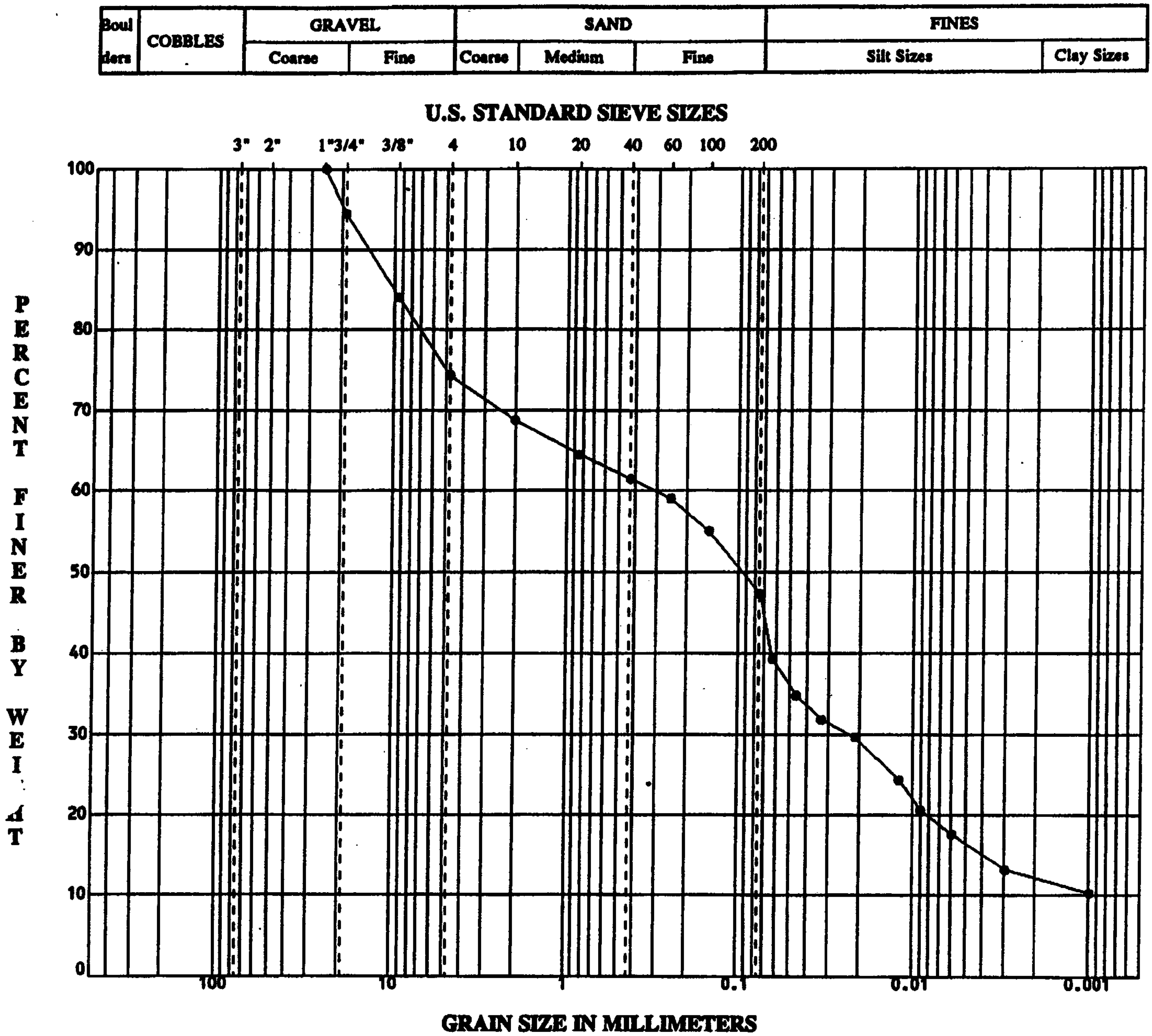
GRAIN SIZE DISTRIBUTION

PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
●						TP-2

GRAIN SIZE DISTRIBUTION

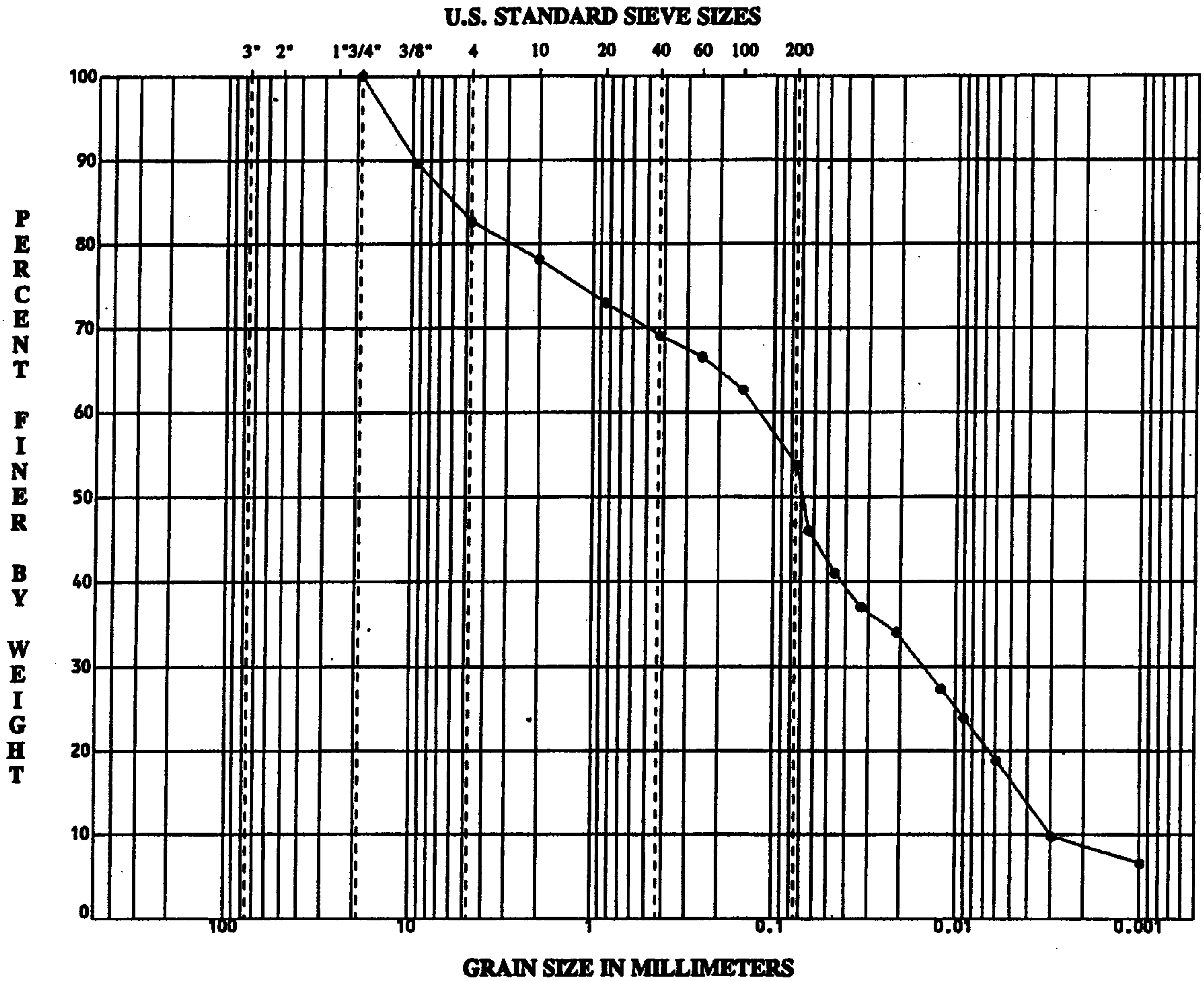
PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING

Boulders	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
●						TP-3

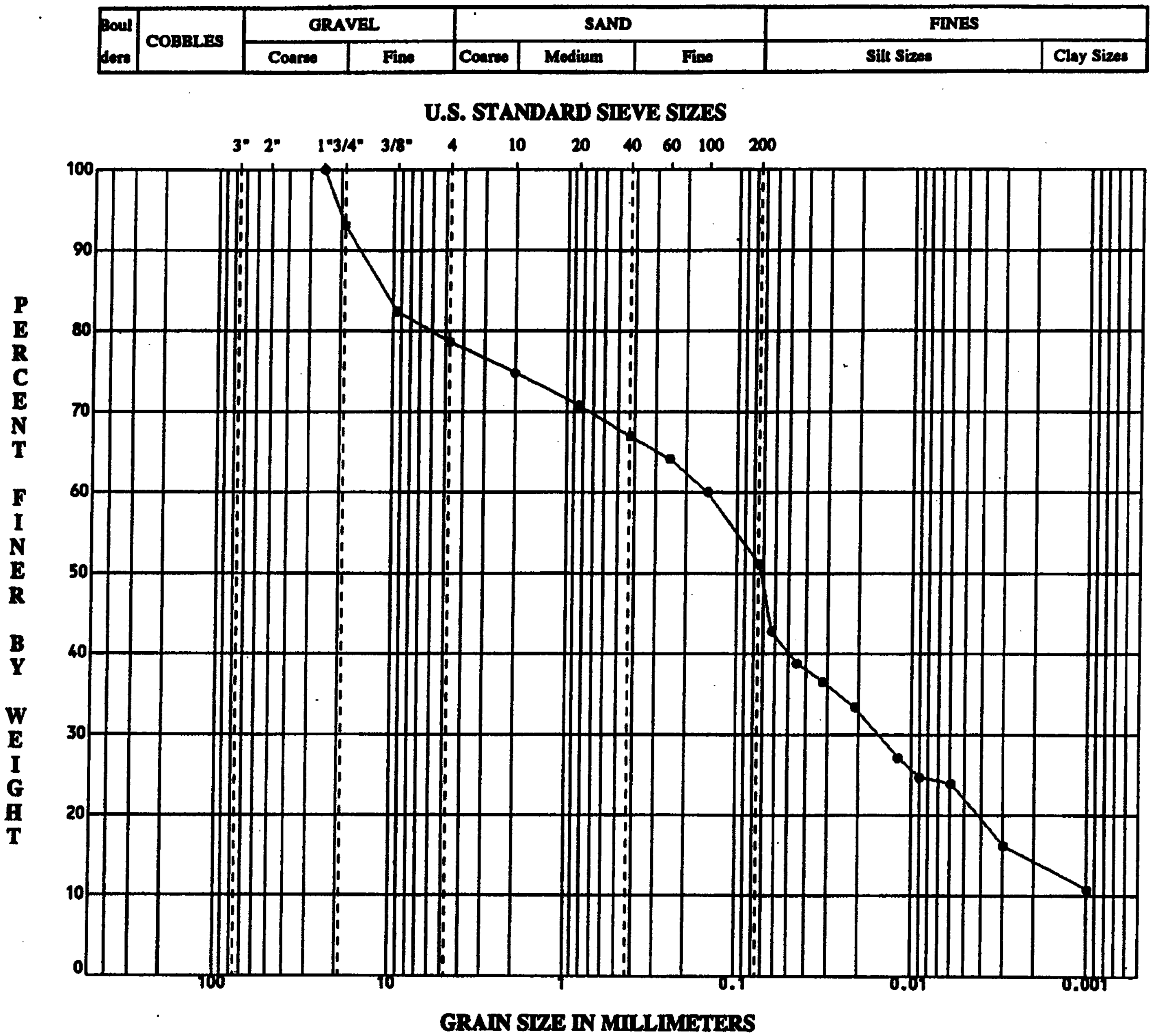
GRAIN SIZE DISTRIBUTION

PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
●						TP-4

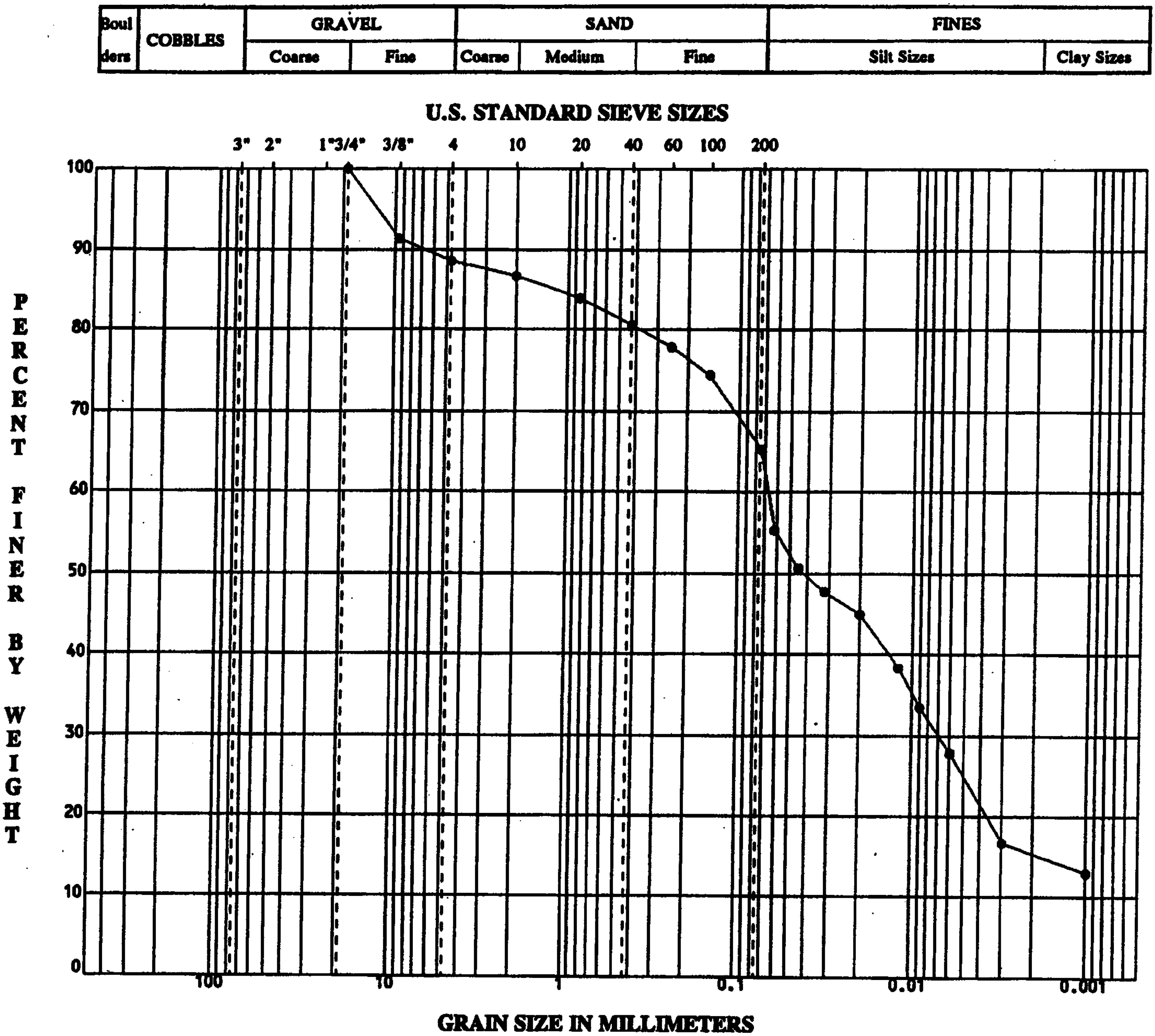
GRAIN SIZE DISTRIBUTION

PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
●						TP-5

GRAIN SIZE DISTRIBUTION

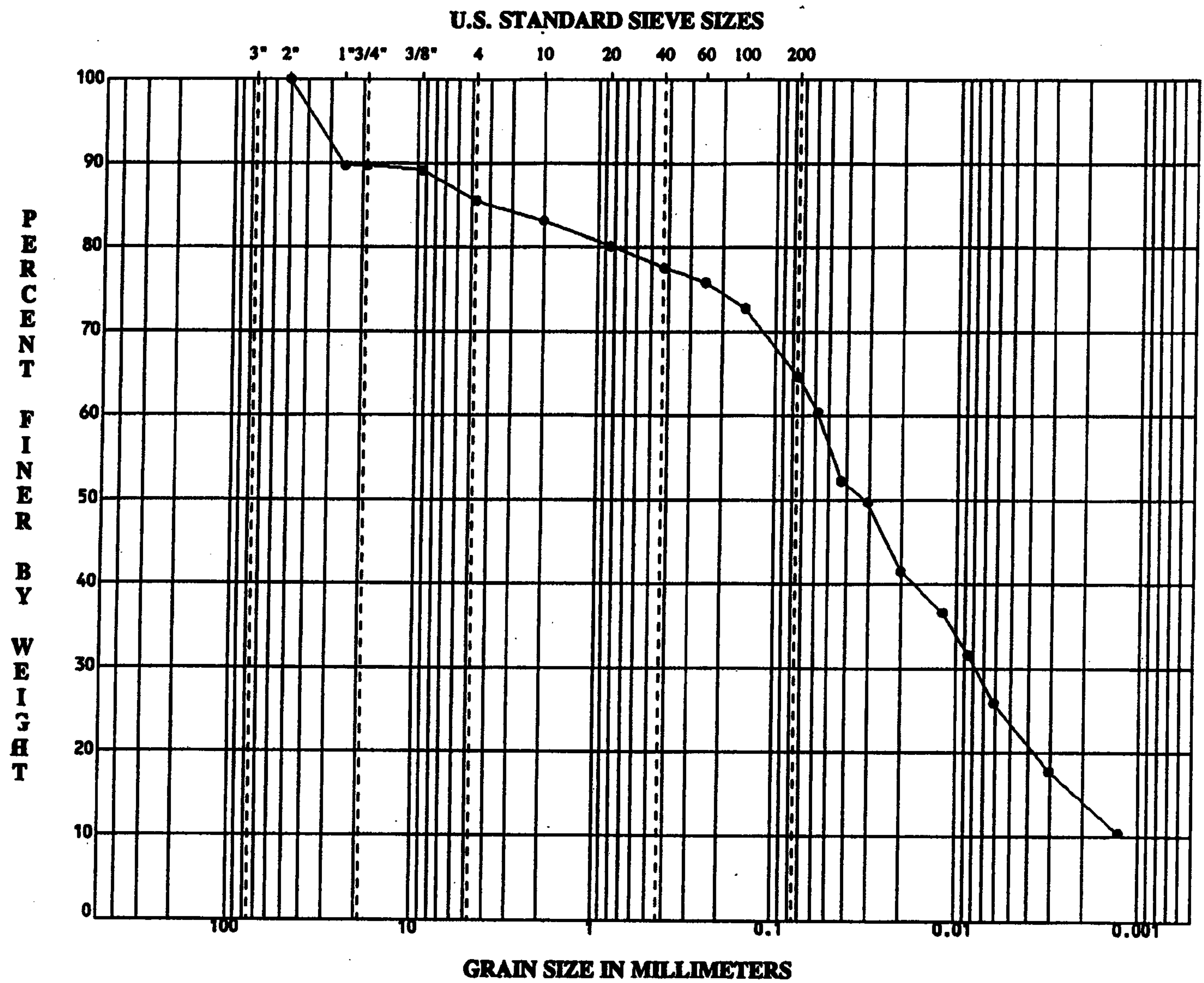
PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING

Boulders	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
●						TP-8

GRAIN SIZE DISTRIBUTION

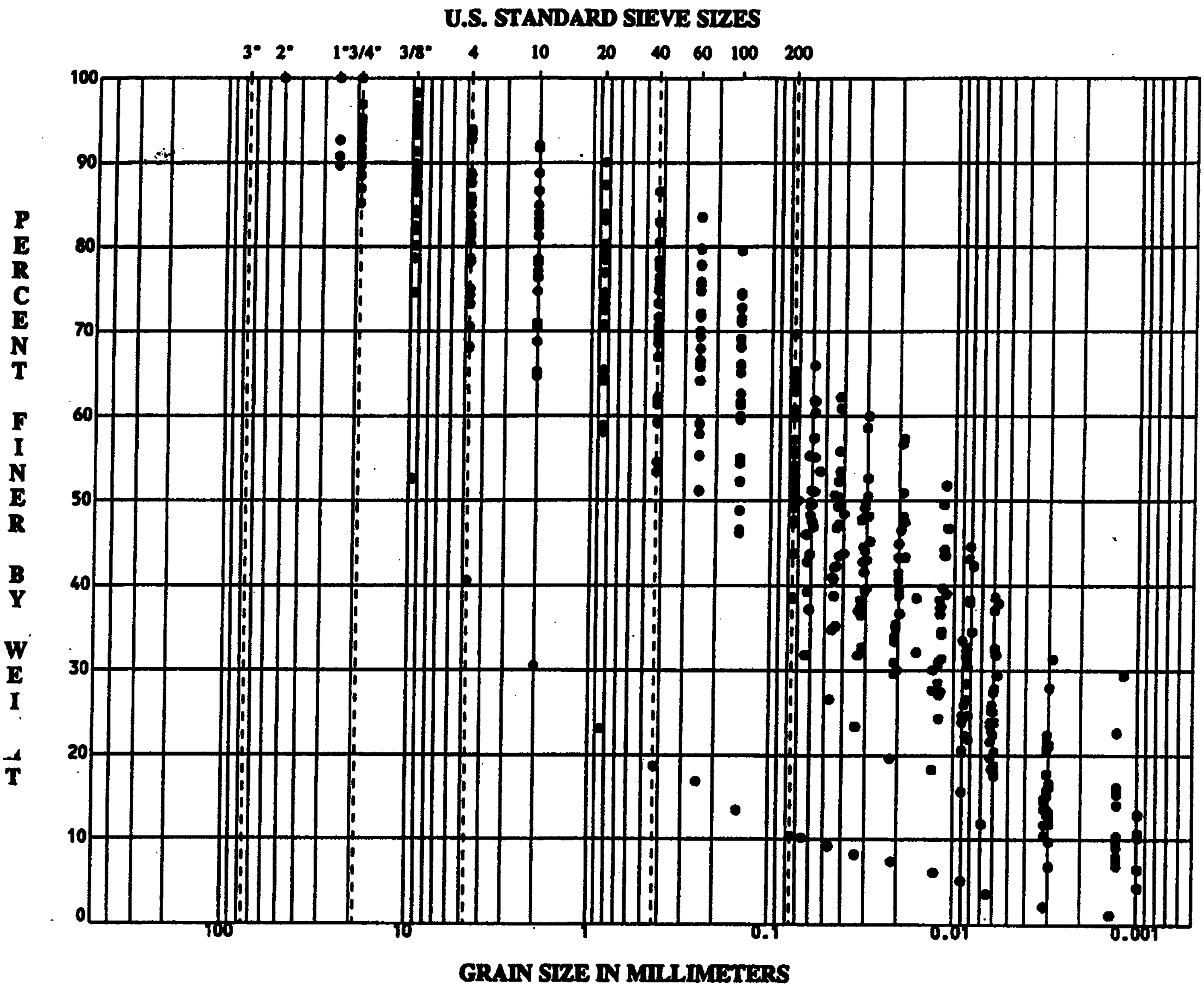
PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING

Boulders	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION

GRAIN SIZE DISTRIBUTION

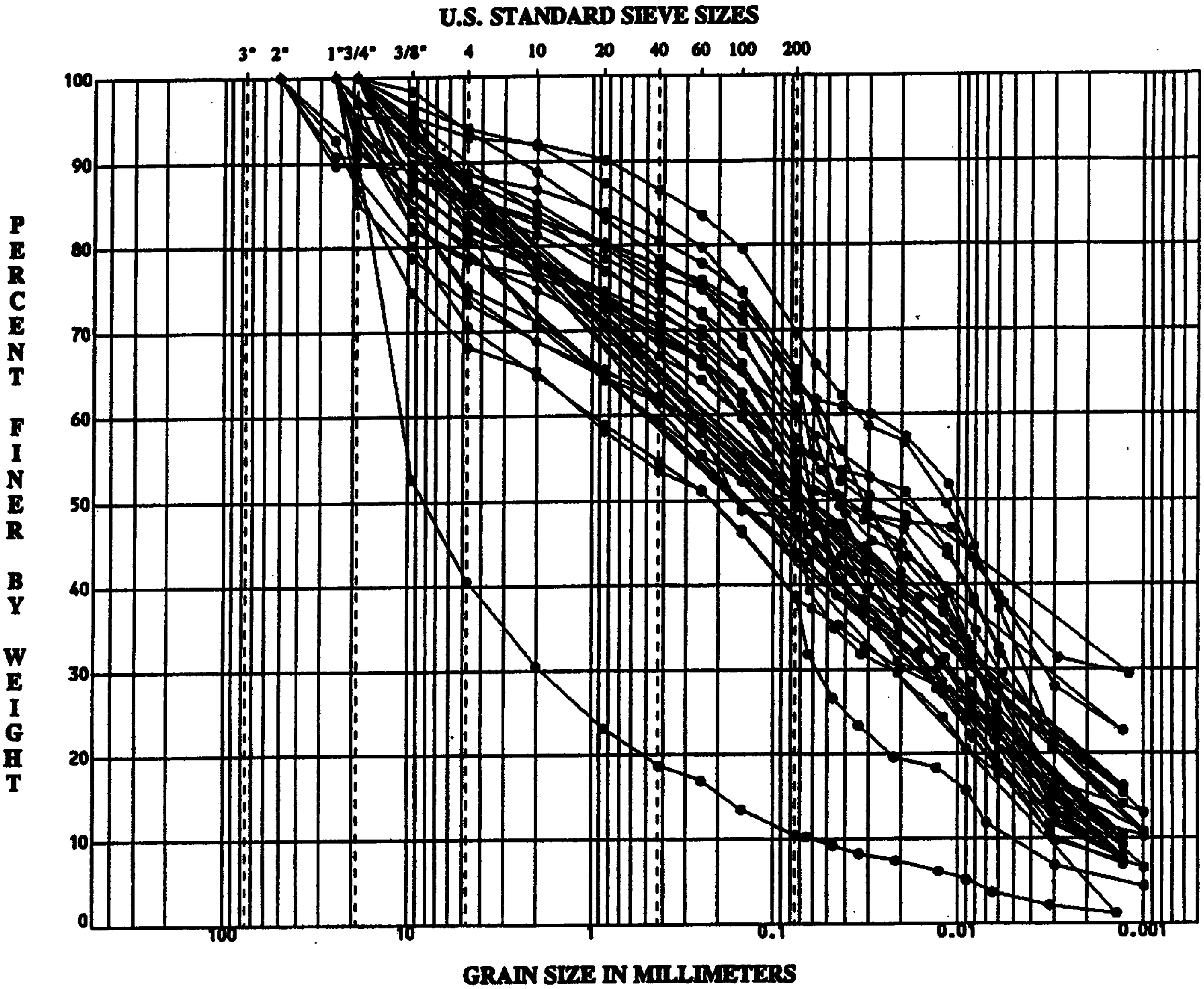
PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING

Boulders	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes



	DEPTH	NAT WC	LL	PL	PI	DESCRIPTION

GRAIN SIZE DISTRIBUTION

PROJECT INFO.

PROJECT NUMBER 482-11280-01

PROJECT Loudoun County Landfill

LAW ENGINEERING

LAW ENGINEERING

4465 Brookfield Corporate Drive, Chantilly, Virginia 22021

REPORT OF FIELD DENSITY TESTS

CLIENT: Loudoun County

JOB NO.: 20310-5-0218.

PROJECT: Woods Road Landfill - Test Pad Construction

TEST NUMBER	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	PROCTOR NUMBER	COMPACTION (%)	SPECIFIED COMPACTION (%)	TEST METHOD	ELEVATION OR DEPTH
		Tests Performed on 07/18/95					
1	18.6	100.8	2	98	95	3	-1'9"
2	20.3	103.7	2	100+	95	3	-1'9"
3	20.8	102.1	2	100	95	3	-1'9"
4	19.4	103.4	2	100+	95	3	-1'6"
5	20.2	102.4	2	100	95	3	-1'6"
6	19.7	103.4	2	100+	95	3	-1'3"
7	21.3	96.3	2	94 <<	95	3	-1'3"
8	20.9	100.6	2	98	95	3	-1'3"
9	19.5	101.3	2	99	95	3	-1'0"
10	20.5	98.6	2	96	95	3	-1'0"
11	20.3	98.7	2	96	95	3	

TEST LOCATIONS:

1	B+5', 1+5'.
2	C+3', 1+5'.
3	D+6', 1+2'.
4	A+15', 1+2'.
5	B+0', 1+3'.
6	B+3', 1+2'.
7	C+7', 1+2'.
8	D+3', 1+4'.
9	A+10', 1+2'.
10	B+4', 1+5'.
11	Retest of test number 7.

TEST COMPARED TO:

PROCTOR NUMBER	MAXIMUM DRY DENSITY (PCF)	OPTIMUM MOISTURE (%)
2	102.5	22.0

REMARKS

Performed In General Accordance With:
3 - ASTM D2922

<< Denotes Less than Specified Compaction

RESPECTFULLY SUBMITTED:

Dan Watkins